

FORM PTO-1390 (REV 10-2000)		U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE		ATTORNEYS DOCKET NUMBER 0670-255	
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371				U.S. APPLICATION NO (if known, see 37 CFR 1.5)	
				09/763958	
INTERNATIONAL APPLICATION NO. PCT/JP99/04614		INTERNATIONAL FILING DATE: August 26, 1999		PRIORITY DATE CLAIMED: August 31, 1998	
TITLE OF INVENTION CARRIER REPRODUCING CIRCUIT					
APPLICANT(S) FOR DO/EO/US Atsushi SHINODA, Kenichi SHIRAISHI					
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:					
<ol style="list-style-type: none"> <li>1. <input checked="" type="checkbox"/> This is a <b>FIRST</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li>2. <input type="checkbox"/> This is a <b>SECOND</b> or <b>SUBSEQUENT</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li>3. <input checked="" type="checkbox"/> This is an express request to promptly begin national examination procedures (35 U.S.C. 371(f)).</li> <li>4. <input checked="" type="checkbox"/> The US has been elected by the expiration of 19 months from the priority date (PCT Article 31).</li> <li>5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2)). <ol style="list-style-type: none"> <li>a. <input type="checkbox"/> is attached hereto (required only if not communicated by the International Bureau).</li> <li>b. <input checked="" type="checkbox"/> has been communicated by the International Bureau.</li> <li>c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US).</li> </ol> </li> <li>6. <input checked="" type="checkbox"/> An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).</li> <li>7. <input checked="" type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)). <ol style="list-style-type: none"> <li>a. <input checked="" type="checkbox"/> are attached hereto (required only if not communicated by the International Bureau).</li> <li>b. <input type="checkbox"/> have been communicated by the International Bureau.</li> <li>c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.</li> <li>d. <input type="checkbox"/> have not been made and will not be made.</li> </ol> </li> <li>8. <input checked="" type="checkbox"/> An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).</li> <li>9. <input checked="" type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).</li> <li>10. <input type="checkbox"/> An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).</li> </ol>					
<b>Items 11 to 16 below concern document(s) or information included:</b>					
11. <input checked="" type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98.					
12. <input checked="" type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.					
13. <input checked="" type="checkbox"/> A FIRST preliminary amendment.					
<input type="checkbox"/> A SECOND or SUBSEQUENT preliminary amendment.					
14. <input type="checkbox"/> A substitute specification.					
15. <input type="checkbox"/> A change of power of attorney and/or address letter.					
16. <input checked="" type="checkbox"/> Other items or information:					
International Search Report					
Six (6) Sheets of Formal Drawings					

U.S. APPLICATION NO (If known, see 37 CFR 1.50) <b>09/763958</b>		INTERNATIONAL APPLICATION NO PCT/JP99/04614		ATTORNEYS DOCKET NUMBER 0670-255	
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<b>17. <input checked="" type="checkbox"/> The following fees are submitted:</b> <b>BASIC NATIONAL FEE (37 CFR 1.492(a)(1) – (5)):</b> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO ..... <b>#1000.00</b>  International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO ..... <b>\$860.00</b>  International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(3)) paid to USPTO ..... <b>\$710.00</b>  International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) ..... <b>\$690.00</b>  International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) ..... <b>\$100.00</b>  <b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b>				<b>CALCULATIONS</b>		<b>PTO USE ONLY</b>	

Surcharge of <b>\$130.00</b> for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$	
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CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	13 - 20 =	0	X \$18.00	\$	
Independent claims	2 - 3 =	0	X \$80.00	\$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ \$270.00	\$270.00	
<b>TOTAL OF ABOVE CALCULATIONS =</b>				\$1,130.00	
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				\$	
<b>SUBTOTAL =</b>				\$ 1,130.00	
Processing fee of <b>\$130.00</b> for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				\$	
<b>TOTAL NATIONAL FEE =</b>				\$ 1,130.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property +				\$40.00	
<b>TOTAL FEES ENCLOSED =</b>				\$1,170.00	
				<b>Amount to be refunded:</b>	\$
				<b>Charged:</b>	\$


a. ☒ A check in the amount of \$1,170.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. \_\_\_\_\_ in the amount of \$ \_\_\_\_\_ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 19-2380. A duplicate copy of this sheet is enclosed.

**NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.**

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 SIGNATURE  
  
 Eric J. Robinson  
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38,285  
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 REGISTRATION NUMBER

## IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re National Phase Patent Application of )  
Atsushi SHINODA et al. )  
International Application No. PCT/JP99/04614 ) Attn: US/DO/EO  
International Filing Date: August 26, 1999 )  
For: CARRIER REPRODUCING )  
CIRCUIT ) Date: February 28, 2001

PRELIMINARY AMENDMENT

Honorable Commissioner for Patents  
Washington, D.C. 20231

Sir:

Please preliminarily amend the subject application as follows:

IN THE SPECIFICATION:

Page 11, line 4, change "Figure 2 is an explanatory view" to -Figures 2(a)-(d) are explanatory views--;

line 7, change "Figure 3 is an explanatory view" to -Figures 3(a)-(d) are explanatory views--;

line 10, change "Figure 4 is an explanatory view" to -Figures 4(a) and (b) are explanatory views--;

line 15, change "Figure 6 is a model wave-form" to -Figures 6(a) and (b) are model wave-forms--;

line 19, change "Figure 8 is an explanatory view" to -Figures 8(a)-(c) are explanatory views--; and

line 21, change "Figure 9 is an explanatory view" to -Figures 9(a) and (b) are explanatory views--.

IN THE CLAIMS:

Please amend claims 5 and 7 as follows:

5. (Amended) The carrier reproducing method according to [any one of claims 1 to 4] any one of claims 1, 2 or 4, characterized in that said predetermined angular velocity ( $\alpha$ ) is an  $\alpha$  having positive polarity or negative polarity.

Claim 7, line 1, change "A carrier reproducing method" to --A synchronous detecting apparatus--.


Please delete claim 9 and add new claim 10 as follows:

--10. The synchronous detecting apparatus according to claim 7 or 8, further comprising a circuit (4) for determining a value of the predetermined time interval taking said auto-correlation, according to said I, Q signals.—

REMARKS

Claim 5 has been amended to correct the multiple dependency therein. Claim 7 has been amended, claim 9 deleted and claim 10 added to correct informalities in the Article 19 Amendment. Examination on the merits is requested.

Respectfully submitted,

  
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## SPECIFICATION

Carrier Reproducing CircuitTechnical Field

5 The present invention relates to carrier reproduction for a BS digital broadcasting receiver, and moreover in particular, relates to a method of implementing carrier reproduction to create reproducing carrier signals with auto-correlation function and a circuit thereof.

10 Background Art

A BS digital broadcasting receiver includes a synchronous detection circuit for detecting PSK modulated waves, and in order to create reproducing carrier signals synchronized with reception signal carriers to be used for synchronous detection, implements carrier reproduction with auto-correlation function. A prior art carrier reproducing circuit is configured as shown in Figure 5.

A PSK modulated signal which was converted to comprise a medium frequency is supplied to two multipliers respectively which configure the synchronous detection circuit 1 and are multiplied by cosine wave data and sine wave data with a multiplier and undergoes synchronous detection. Multiplication output I data as well as Q data outputted from the synchronous detection circuit 1 are supplied to two digital low pass filters respectively which configure a digital low pass filter 3 and the high digit frequency components which are being respectively outputted from the synchronous detection circuit 1

are removed so that the I data as well as the Q data being baseband signals are sent out.

An output baseband signal from the digital low pass filter 3 includes as shown in Figure 6 a first to a forty-eighth slots transmitting a TMCC section as well as information to the head of one frame. A TMCC is a Transmission and Multiplexing Configuration Control signal and transmits slot number information to designate transmission method (designate modulation method or error correction code substituting ratio) as well as to control time slots so as to correctly decode bit information at the phase point of demodulation with the TMCC information. A TMCC section is a period of time during when the TMCC signal is sent. The I data as well as the Q data are supplied to the Transmission and Multiplexing Configuration Control signal (TMCC) section detecting circuit 4 so that the TMCC section is detected in the TMCC section detecting circuit 4 and the signal showing the TMCC section width (192 symbols) is outputted.

On the other hand, the I data as well as the Q data being baseband signals outputted from the digital low pass filter 3 are supplied to a signal point arrangement converting circuit 5 and are converted into a signal point position signal based on the I data as well as the Q data being output base band signals from the digital low pass filter 3. The signal point position signal subject to conversion in the signal point arrangement converting circuit 5 is supplied to a phase detector 6 and undergoes phase detection.

The phase detection output from the phase detector 6 is supplied to the auto-correlation function determining circuit 7 together with the above described TMCC section width signal so that the auto-correlation function is obtained over the TMCC section width from the phase detection output and the delayed phase detection output subject to delay for time  $\tau$  on the phase detection output. A signal based on the period of the obtained auto-correlation function wave-form represents a shift of the oscillation frequency of the NCO 2 from the carrier frequency, and this signal is supplied to the numerical control oscillator (NCO) 2 from the auto-correlation function determining circuit 7. In the NCO 2, the signal based on the period of the auto-correlation function wave-form outputs cosine wave data as well as sine wave data of the reproducing carrier signal having the frequency synchronized with the carrier from the NCO 2 which are supplied to the multiplier of the synchronous detection circuit 1 and are multiplied by the I data as well as the Q data so that carrier reproduction is implemented.

Here, as described above, involvement of method to detect the auto-correlation in the carrier reproducing circuit is known to be strong against noises.

The frame configuration of the BS digital broadcast has as shown in Figure 6(a) at its head following a frame synchronization (not shown) the header information modulated with BPSK called TMCC and the TMCC section is formed with 192 symbols.

Here in the case where the oscillation frequency in the NCO is shifted from the carrier frequency, the phase detection output of the TMCC signal in the TMCC section will become a sawtooth wave a as shown with broken lines in Figure 6(b). When the C/N is sufficiently high, a beautiful sawtooth wave as shown with broken lines a is reproduced. In addition, since the period of this sawtooth wave represents a shift frequency of the oscillation frequency of the NCO 2, the differential coefficient as well as the period of the sawtooth wave a can be measured directly. However, when C/N is low, signals based on noises are multiplexed onto the sawtooth wave a due to noises to give rise to the one shown in the solid line wave-form b in Figure 6(b), and as for differential coefficient as well as period, it will become impossible to measure its period T directly from the wave-form b.

Especially, when the phase of the signal point position signal is near 90 degrees, for example, in the case of position designated with A in Figure 6(b) and Figure 5, the detection phase will exceed 90 degrees even with a tiny noise component, but since a signal exceeding +90 degrees is detected as -90 degrees, an enormously large detection error will be given rise to. Figure 7 shows constellation of a signal point position signal and the oblique line portion shows an uneven range of the signal point position signal.

Therefore, a signal wave-form b including noises is not directly measured to measure oscillation frequency shift of the NCO 2, but with auto-correlation function, noises are reduced. In the case where the input signal is a period function, the auto-correlation



function will become a period function with the same period. Since this auto-correlation function is a signal processing which is strong against noises, the period of the input signal can be correctly obtained from this auto-correlation function also in the case where  
5 noises exist. Accordingly, the phase detection output of the wave-form b in Figure 6(b) will not be measured for its period directly, but the auto-correlation function is obtained and the period of its wave-form is measured.

Figure 8 is an explanatory view of calculation of an  
10 auto-correlation function as well as of its wave-form. The phase detection output wave-form from the phase detector 6 is as shown in Figure 8(a), where the wave-form b in Figure 6(b) was redescribed to be represented by  $\theta(t)$ , and Figure 8(b) shows wave-form  $\theta(t+\tau)$  subject to delay time  $\tau$  from the wave-form in Figure 8(a), where  
15 auto-correlation function  $\Phi(\tau)$  is calculated over the balance section by subtracting the delay time  $\tau$  from the TMCC section detected by the TMCC section detecting circuit 4. In Figure 8(b), it is described as an arithmetic operation section. The auto-correlation function  $\Phi(\tau)$  is expressed in an equation to become the one shown in the  
20 following equation (1):

$$\Phi(\tau) = \sum \{ \theta(t) - \theta_{ave} \} \{ \theta(t+\tau) - \theta_{ave} \} \quad \dots (1)$$

In the equation (1),  $\theta(t)$  denotes a phase detection output with an adding section being an arithmetic operation section from 0 to  $(M-1-\tau)$ . Here, reference character M denotes a symbol number of an  
25 observation section, that is, a symbol number of a TMCC section, and

in the BS digital broadcast the symbol number of the TMCC section is 192.  $\theta_{ave}$  denotes an average value within the observation section of the phase detection output. The operated auto-correlation function is shown in Figure 8(c). In a portion of a predetermined amplitude level of this auto-correlation function, zero cross of the auto-correlation function  $\Phi(\tau)$  wave-form is obtained to obtain an average period T.

An average period T is the average period  $T=\pi/\omega$ , wherein  $\omega$  is an angular velocity of alienation frequency, and here the alienation frequency  $\omega$  denotes a shift between the oscillation frequency (reproducing carrier frequency) of NCO 2 and the carrier frequency. An alienation frequency is also described as a shift frequency. The angular velocity  $\omega$  is obtained from the average period T and is supplied to the NCO 2 so as to give rise to a sine wave and a cosine wave of the angular velocity  $\omega$  in the NCO 2 to be sent out to the synchronous detection circuit 1 so that carrier reproduction is implemented.

However, with the above described prior art carrier reproducing circuit, there is a problem that the direction of frequency shift, that is, polarity cannot be detected. That is, with this method of obtaining an auto-correlation function, for any of shift of oscillation frequency of the NCO 2 from the carrier which could be  $+\Delta\omega$  or  $-\Delta\omega$ , wave-forms of the auto-correlation function being an output of the auto-correlation circuit 7 is the same, and therefore alienation

frequency is required to undergo polarity judgment, but polarity judgment cannot be implemented.

In order to avoid the issue of polarity judgment on the alienation frequency, there is a possibility that the oscillation frequency of the NCO 2 is shifted in advance to the initial state at the time of synchronous detection. With the frequency for shifting being made to be  $\alpha$ , if this  $\alpha$  is set at a value not less than the expected maximum alienation frequency of the NCO 2, then for the alienation frequency  $\omega$  not more than that, the direction of polarity is determined to one. That is, as shown in Figure 9(a), with the reproducing carrier frequency of the phase detection output being set at the center of the expected maximum alienation frequency range of the NCO 2, polarity judgment cannot be implemented.

Nevertheless, as shown in Figure 9(b), with the reproducing carrier frequency being set at the minimum frequency of the expected maximum alienation frequency range of the NCO 2, polarity being negative will not take place (, that is, the oscillation frequency of the NCO 2 is always higher than the reproducing carrier frequency), the polarity is positive, and in this relation, it will not take place that polarity judgment cannot be implemented. However, the range in which the TMCC section is detected is the expected maximum alienation frequency range shown in Figure 9(a) with the reproducing carrier frequency at the center, and therefore, direct application of this method to a carrier reproducing circuit in a BS digital broadcasting receiver will give rise to a problem that a portion where

any TMCC section cannot be detected or in this example a crosshatched portion in the rightward half from the dotted line in Figure 9(b) will be generated.

Accordingly, since the auto-correlation function at the time of carrier reproducing in a BS digital broadcasting receiver is operated based on the TMCC section, an indispensable condition is that the TMCC section can be detected, and when no TMCC section will become detectable, no auto-correlation function will be given by operation.

As another problem different from the polarity judgment of alienation frequency, when the alienation frequency  $\Delta\omega$  becomes too much small, the period of auto-correlation function  $T=\pi/\omega$  will increase, giving rise to a problem that one period of auto-correlation function will not be contained within a TMCC section at a constant period and the period  $T$  cannot be obtained so that carrier reproduction cannot be implemented.

Objects of the present invention are to provide a carrier reproducing circuit capable of judging the polarity of alienation frequency in a carrier reproducing circuit using auto-correlation function to implement carrier reproduction, and to solve the problem that carrier reproduction cannot be implemented when alienation frequency is small.

#### Summary of the Invention

A carrier reproducing method of a PSK modulated signal according to the present invention comprises steps of synchronously detecting the PSK modulated signals with a reproducing carrier signal from an oscillator to create a synchronous detecting signal,  
5 phase-detecting the above described synchronous detecting signal to create a phase detecting signal, creating an auto-correlation function outputs taken over a predetermined time interval (TMCC period) on the above described phase detecting signal, applying a control signal based on a period of the above described auto-correlation function  
10 output to the above described oscillator to make reproducing control signal from said oscillator synchronize with carrier of the PSK modulated signal, characterized in that a phase rotation of a predetermined angular velocity ( $\alpha$ ) is given to the above described phase detecting signal so that on the phase detecting signal to which  
15 the above described phase rotation is given, the auto-correlation function output taken over the above described predetermined time interval is created.

A carrier reproducing circuit of PSK according to the present invention is a circuit comprising an oscillator (NCO) for outputting a  
20 reproducing carrier signal, a synchronous detection circuits (1, 3) for synchronously detecting a reception PSK modulated signal with the above described reproducing carrier signal to create I, Q signals, a signal point arrangement converting circuit (5) for implementing a signal point arrangement conversion on the above described I, Q  
25 signals to create a signal point arrangement conversion signal, a

phase detecting circuit (6) for phase-detecting the above described signal point arrangement conversion signals to create phase detecting signals, and an auto-correlation detection circuit (7) for taking an auto-correlation over a predetermined time interval on the above  
5 described phase detecting signals to produce an auto-correlation function output and for giving to the above described oscillator a signal based on the auto-correlation function output to control an oscillation frequency of the above described oscillator, characterized by a phase rotation circuit (8) for causing the above described phase  
10 detecting signal to phase-rotate by a predetermined angular velocity ( $\alpha$ ).

Accordingly, according to the present invention, instead of making frequencies of the sine wave data as well as the cosine wave data shift in order to judge polarity of frequency shift, the phase  
15 detecting signal is caused to phase-rotate to compensate this phase-rotating portion and the oscillation frequency of a numerical control oscillator is controlled, and therefore the numerically controlled oscillation frequency is not shifted, and a signal for transmission multiplexed configuration control signal section  
20 detection is not phase-rotated, and therefore the TMCC sections are always detected so that the auto-correlation can be obtained and polarity judgment on frequency shift will become feasible.

#### Brief Description of the Drawings

Figure 1 is a block diagram showing the configuration of a carrier reproducing circuit according to an embodiment of the present invention;

5 Figure 2 is an explanatory view showing the operation of a carrier reproducing circuit according to an embodiment of the present invention;

Figure 3 is an explanatory view showing the operation of a carrier reproducing circuit according to an embodiment of the present invention;

10 Figure 4 is an explanatory view showing the operation of a carrier reproducing circuit according to an embodiment of the present invention;

Figure 5 is a block diagram showing the configuration of a prior art carrier reproducing circuit;

15 Figure 6 is a model wave-form graph showing outputs of a phase detecting circuit;

Figure 7 is a model view showing constellation of a signal point position signal;

20 Figure 8 is an explanatory view showing calculation of an auto-correlation function as well as wave-forms thereof; and

Figure 9 is an explanatory view to be served to explain the operation of a prior art carrier reproducing circuit.

#### Detailed Description of the Preferred Embodiments

A carrier reproducing circuit according to the present invention will be described by way of an embodiment as follows.

Figure 1 is a block diagram showing a configuration of a carrier reproducing circuit according to an embodiment of the present invention.

In the carrier reproducing circuit according to an embodiment of the present invention, PSK modulated signals having been converted to a medium frequency is respectively supplied to a multiplier 11 and a multiplier 12 configuring a synchronous detection circuit 1, multiplied by cosine data and sine data in the multiplier 11 and the multiplier 12 and synchronously detected by I data and Q data being baseband signals. The multiplier output I data and Q data outputted from the synchronous detection circuit 1 are respectively supplied to a digital low pass filter 31 and a digital low pass filter 32 configuring a digital low pass filter 3 so that a high digit frequency component in respective outputs from the synchronous detection circuit 1 are removed and the I data as well as Q data being baseband signals are sent out.

The I data as well as the Q data being output baseband signals from the digital low pass filter 3 are supplied to a decoder for demodulating information portions and are supplied to the section detecting circuit 4 so that TMCC sections are detected in a TMCC section detecting circuit 4 and signals having width of the TMCC section is sent out to the auto-correlation function determining circuit 7.



On the other hand, outputs from the digital low pass filters 31 and 32 are supplied to a signal point arrangement converting circuit 5 and are converted into signal point position signals based on the I data and the Q data being output baseband signals from the digital low pass filters 31 and 32. A signal point position signal converted in the signal point arrangement converting circuit 5 is substantially a vector up to a signal point position. This signal point position signal is supplied to the phase rotation circuit 8 so that the signal point position signal is caused to phase-rotate at a predetermined angular velocity  $\alpha$  determined in advance for each symbol in a TMCC section. Phase rotation is implemented by sine and cosine signals of an angular velocity  $\alpha$  being multiplied respectively by the I and the Q signals. The signal point position signals subject to phase rotation are supplied to a phase detector 6 and undergo phase detection.

Here, a predetermined angular velocity  $\alpha$  determined in advance for each symbol is determined based on a expected oscillation frequency range of NCO 2, and with a large expected oscillation frequency range, the angular velocity  $\alpha$  is set with a fast value.

The phase detection output from the phase detector 6 is supplied to the auto-correlation function determining circuit 7 so that an auto-correlation function  $\Phi(\tau)$  is obtained from the phase detection output and a delayed phase detection output subject to a delay by time  $\tau$  from the phase detection output. Once a period  $T$  of the obtained auto-correlation function wave-form is obtained and the alienation frequency at the time when synchronous operation of the

NCO 2 starts is represented by  $\omega$ , an angular velocity  $(\omega+\alpha)$  is obtained from relationship of the period  $T=\pi/(\omega+\alpha)$ . Here, the angular velocity  $(\omega+\alpha)$  is adopted since phase rotation is caused to take place at an angular velocity  $\alpha$  with the phase rotation circuit 8.

5       The angular velocity  $\alpha$ , which has been caused to phase-rotate from the obtained angular velocity  $(\omega+\alpha)$  with the phase rotation circuit 8, is subtracted in the subtracting circuit 9, and the output from the subtracting circuit 9 is supplied to the NCO 2 as a control voltage having polarity corresponding with the size of the alienation  
10 frequency  $\omega$ . In the NCO 2, the control voltage is fed back so that the alienation frequency  $\omega$  becomes 0, and as a result hereof, cosine wave data  $\cos$  as well as sine wave data  $\sin$  of reproducing carrier signals synchronized with carriers is outputted and is respectively supplied to the multiplier 11 and the multiplier 12 of the  
15 synchronous detection circuit 1 to be multiplied by the I data and the Q data.

Here, in the carrier reproducing circuit according to an embodiment of the present invention, instead of causing the oscillation frequency of the NCO 2 to shift in order to implement  
20 polarity judgment on the alienation frequency  $\omega$  calculated with the auto-correlation function determining circuit 7, that is, polarity judgment of frequency shift, the signal point position signals are caused to phase-rotate with the phase rotation circuit 8, but as for I and Q signals inputted into a TMCC section detecting circuit 4, they  
25 are not caused to phase-rotate. Accordingly, this phase rotation

does not influence detection of the TMCC section in the TMCC section detecting circuit 4.

By implementing phase rotation at the angular velocity  $\alpha$  with the phase rotation circuit 8, a phase detection output of the phase detector 6 is also caused to phase-rotate at an angular velocity equivalent to  $\alpha$ , and is caused to change at an angular velocity equivalent to  $\alpha$  to be outputted from the auto-correlation function determining circuit 7. The phase rotation by the angular velocity  $\alpha$  in the phase rotation circuit 8 will be imitatively given the same setting as in case of shifting the phase detecting frequency to the one end side in the expected alienation frequency range as shown in Figure 9(b). Thereby, polarity judgment of the alienation frequency will be able to be implemented. Moreover, the angular velocity  $\alpha$ , which was added by the phase rotation circuit 8 from the angular velocity  $(\omega+\alpha)$  outputted from the auto-correlation function determining circuit 7, has been supplied to the NCO 2 to be subtracted with the subtracting circuit 9, and the oscillation frequency itself of the NCO 2 is not shifted in advance, and therefore detection in the TMCC section will not be influenced anyhow. Incidentally, the NCO may be a voltage control oscillator (VCO).

This polarity judgment would be described further as follows. With carrier frequency being  $\omega_c$  and oscillation frequency (reproducing carrier frequency) of the NCO 2 being  $\omega_n$ , in the case of  $\omega_c > \omega_n$ , phase detection outputs from the phase detector 6 without phase rotation  $\alpha$  with alienation frequency being  $+\omega_0$  are shown in

Figure 2(a). In Figure 2 as well as in Figure 3 to be described later, circular points represent symbol positions and inclination between the adjacent symbols is the alienation angular frequency  $\omega_0$ . Phase detection outputs when the phase detection outputs are caused to phase-rotate in the positive direction at an angular velocity  $+\alpha$  are as shown in Figure 2(b), and inclination between symbols will be  $(\omega_0+\alpha)$ . Since  $+\omega_0$  has the same polarity as  $+\alpha$ ,  $(\omega_0+\alpha)$  is larger than  $\alpha$ . Accordingly,  $(\omega_0+\alpha)-\alpha$  being an output of the subtracting circuit 9 has positive polarity.

Figure 2(c) further shows how it looks like when phase rotation is caused to take place at an angular velocity  $\alpha$  for a symbol, wherein arrows show how it looks when phase rotation is caused to take place at an angular velocity  $\alpha$  for each symbol while broken lines show how it looks like when returning is taking place in excess of  $\pi/2$  radian.

Figure 2(d) shows phase detection output of the phase detector 6 corresponding with Figure 2(c).

With the alienation angular frequency being  $-\omega_1$  at the time of  $\omega_c < \omega_n$ , the phase detection outputs from the phase detector 6 are shown in Figure 3(a). The phase detection outputs at the time when the phase detection outputs are caused to phase-rotate at an angular velocity  $+\alpha$  are as shown in Figure 3(b), where inclination between symbols will become  $(-\omega_1+\alpha)$  as a result of phase rotation at an angular velocity  $+\alpha$ . Since  $-\omega_1$  and  $+\alpha$  are different in polarity,  $(-\omega_1+\alpha)$  is smaller than  $\alpha$ . Accordingly,  $(-\omega_0+\alpha)-\alpha$  being an output from the subtracting circuit 9 will have negative polarity. That is,

the outputs  $(-\omega_0 + \alpha)$  and  $(-\omega_1 + \alpha)$  of the auto-correlation detection circuit 7 do not have polarity, but for the outputs of the subtracting circuit 9, polarity appears based on whether the oscillation frequency  $\omega_n$  of the NCO 2 is higher or lower than the carrier frequency  $\omega_c$ .

5        Figure 3(c) further shows how it looks like when phase rotation is caused to take place at an angular velocity  $\alpha$  for a symbol, wherein arrows show how it looks when phase rotation is caused to take place at an angular velocity  $\alpha$  for each symbol while broken lines shown how it looks like when returning is taking place in excess of  $\pi/2$  10        radian. Figure 3(d) shows phase detection output of the phase detector 6 corresponding with Figure 3(c). Thus, phase rotation at an angular velocity  $\alpha$  for a symbol will cause polarity of the phase detection output to be positively converted and will be the same as in the case described in the polarity judgment in Figure 9(b).

15        As direction of phase rotation, positive  $\alpha$  or negative  $\alpha$  can be adopted. Adopting positive angular velocity  $\alpha$ , when the reproducing carrier frequency is higher than carrier frequency, that is, positive  $\omega$ , the phase detection output  $(\omega + \alpha)$  will have its absolute value becoming larger than  $\omega$  for a portion equivalent to  $\alpha$ , and when it is 20        lower (, that is, negative  $\omega$ ), the phase detection output  $(\omega + \alpha)$  will have its absolute value becoming smaller than  $\omega$  for a portion equivalent to  $\alpha$ . Adoption of a negative angular velocity  $\alpha$  will give rise to a reversed relationship, but it will remain same that alienation frequency of correct polarity will be obtained.

In addition, when  $(\omega+\alpha)$  approaches zero,  $T=\pi/(\omega+\alpha)$  will become longer than the width of the TMCC section, and outputs of auto-correlation detection circuit will become unavailable. Accordingly,  $|\alpha|$  is selected to be larger than  $|\omega|$  having  $\pm\omega$  of range width of the expected frequency of the NCO 2 by  $\Delta\omega$  so that  $(\omega+\alpha)$  always becomes larger than a predetermined value, for example  $\Delta\omega$ . Here,  $\Delta\omega$  is selected so that  $\pi/\Delta\omega$  becomes shorter than the width of the TMCC section. For example, with  $\pm\omega=\pm 1$  MHz,  $|\alpha|=1.2$  MHz will give rise to  $\Delta\omega=0.2$  MHz, and the minimum value of frequency of the phase detecting signal  $(\omega+\alpha)$  is 0.2 MHz. Accordingly, the period will be made to become  $T=\pi/0.2\times 10^{-6} \approx 15.8 \mu s < \text{width of TMCC section}$ . With selection of such  $\alpha$ , outputs of auto-correlation detection circuit always can be obtained, and outputs of the subtracting circuit gives rise to positive or negative polarity based on the fact that the oscillation frequency of the NCO 2 is either higher or lower than the carrier frequency, and therefore, with the NCO 2 being controlled appropriately, the NCO 2 can output reproducing carriers synchronized with carriers.

In the present embodiment, the input of the phase detector 6 is phase-rotated with phase rotation by the phase rotation circuit 8, that is, vectors of the baseband signals inputted into the phase detector 6 are phase-rotated for phase detection with the phase detector 6, and therefore the angular velocity  $\alpha$  is set so that as shown in Figure 4(a), the phase detecting frequency is positioned at a frequency exceeding the expected maximum frequency range, that is,

the right end in Figure 4(b) when the expected maximum frequency range was arranged to be positioned at a blank in the frequency range where carriers do not exist from the phase detecting frequency as shown in Figure 4(b) from approximately the center of the expected maximum frequency range. Incidentally, the phase rotation may be implemented onto the I and the Q signals inputted into the signal point arrangement converting circuit 5.

Making setting like this, polarity of the alienation frequency will not be negative, substantially enabling polarity of the alienation frequency to be judged. In addition, presence of the blank section makes the alienation frequency too little, and therefore such a case that one period is not contained within a TMCC section and no periods will become obtainable will not take place.

As described above, according to the carrier reproducing circuit of the present invention, causing the vectors of the baseband signals to phase-rotate, and compensating portions of phase rotation after auto-correlation detection, polarity of the alienation frequency always can be judged.

CLAIMS in AMENDMENT

[On January 31, 2000 (31.01.00) in receipt by the international bureau: claim 4 at the time of filing the present application was  
5 withdrawn; claims 1, 5, 6, and 8 to 10 at the time of filing the present application were corrected; the other claims are unchanged. (3 pages)]

1. A carrier reproducing method of a PSK modulated signal,  
10 comprising steps of:

synchronously detecting the PSK modulated signals with a reproducing carrier signal from an oscillator to create a synchronous detecting signal;

15 phase-detecting said synchronous detecting signal to create a phase detecting signal;

creating an auto-correlation function output taken over a predetermined time interval (TMCC period) on said phase detecting signal; and

20 applying a control signal based on a period of said auto-correlation function output to said oscillator to make a reproducing control signal from said oscillator synchronize with a carrier of the PSK modulated signal,

25 characterized in that a phase rotation of a predetermined angular velocity ( $\alpha$ ) which is larger than a maximum expected alienation frequency of said oscillator with respect to the carrier frequency to said phase detecting signal so that on the phase detecting signal to which said phase rotation is given, the



auto-correlation function output taken over said predetermined period is created.

2. The carrier reproducing method according to claim 1,  
5 characterized in that said synchronous detecting signal is a signal point arrangement conversion signal obtained by multiply-detecting said reproducing carrier signal and the PSK modulated signal to create I, Q signals and implementing a signal point arrangement conversion for said I, Q signals, and the phase rotation of a  
10 predetermined angular velocity ( $\alpha$ ) to said phase detecting signal is a phase-rotation of the predetermined angular velocity ( $\alpha$ ) taken for said signal point arrangement conversion signal.

3. The carrier reproducing method according to claim 1 or 2,  
15 characterized in that said control signal having a polarity is created from a value derived by subtracting said predetermined angular velocity ( $\alpha$ ) from an angular velocity ( $\omega + \alpha$ ) corresponding with a period of said auto-correlation function.

20 4. The carrier reproducing method according to claim 1, characterized in that a period (T) corresponding with a difference between said predetermined angular velocity ( $\alpha$ ) and a maximum one of said expected alienation frequency is selected so as to become smaller than a predetermined time interval taking said correlation.

5. The carrier reproducing method according to any one of claims 1 to 4, characterized in that said predetermined angular velocity ( $\alpha$ ) is an  $\alpha$  having positive polarity or negative polarity.

5 6. The carrier reproducing method according to claim 2, characterized in that said I, Q signals are inputted and a predetermined time interval width taking said auto-correlation is determined from said I, Q signals.

10 7. A carrier reproducing method of a PSK modulated signal, comprising:

an oscillator (NCO) for outputting a reproducing carrier signal;

a synchronous detection circuits (1, 3) for  
synchronously-detecting a reception PSK modulated signal with said  
15 reproducing carrier signal to create I, Q signals;

a signal point arrangement converting circuit (5) for  
implementing a signal point arrangement conversion on said I, Q  
signals to create a signal point arrangement conversion signal;

a phase detecting circuit (6) for phase-detecting said signal  
20 point arrangement conversion signal to create a phase detecting  
signal; and

an auto-correlation detection circuit (7) for taking an  
auto-correlation over a predetermined time interval on said phase  
detecting signals to produce an auto-correlation function output and  
25 for giving to said oscillator a signal based on the auto-correlation  
function output to control an oscillation frequency of said oscillator,

characterized by a phase rotation circuit (8) for causing said signal point arrangement signal to phase-rotate by a predetermined angular velocity ( $\alpha$ ) which is larger than a maximum expected alienation frequency of said oscillator with respect to a carrier  
5 frequency.

8. The synchronous detecting apparatus according to claim 7, further comprising a subtracting circuit (9) for subtracting a value corresponding with said predetermined angular velocity from a signal  
10 based on said auto-correlation function output.

9. In the carrier reproducing circuit according to claim 7 or 8, a synchronous detecting apparatus including a circuit (4) to which said I, Q signals are inputted and which determines a predetermined time  
15 interval taking said auto-correlation, from said I, Q signals.

ABSTRACT

A carrier reproducing circuit capable of judging the polarity of alienation frequency. A TMCC section is detected from the synchronous detection output from a synchronous detection circuit (1) by a TMCC section detecting circuit (4), the synchronous detection output is converted to a signal point arrangement by a signal point arrangement converting circuit (5), the phase of the converted signal point position signal is rotated at a predetermined angular velocity for each symbol of the TMCC by a phase rotating circuit (8), the signal position signal whose phase is rotated is phase-detected by a phase detector (6), an auto-correlation function of the phase detection output in the TMCC section is determined by an auto-correlation function determining circuit (7) and angular velocity information based on the period of the waveform of the determined auto-correlation function is obtained, the phase-rotation angular velocity at the phase rotation circuit (8) is subtracted from the obtained angular velocity by a subtracting circuit (9), and sine and cosine wave data on frequency based on the output of the subtraction are generated and sent to the phase detection circuit (1) by a numerical control oscillator (2).

FIG. 1

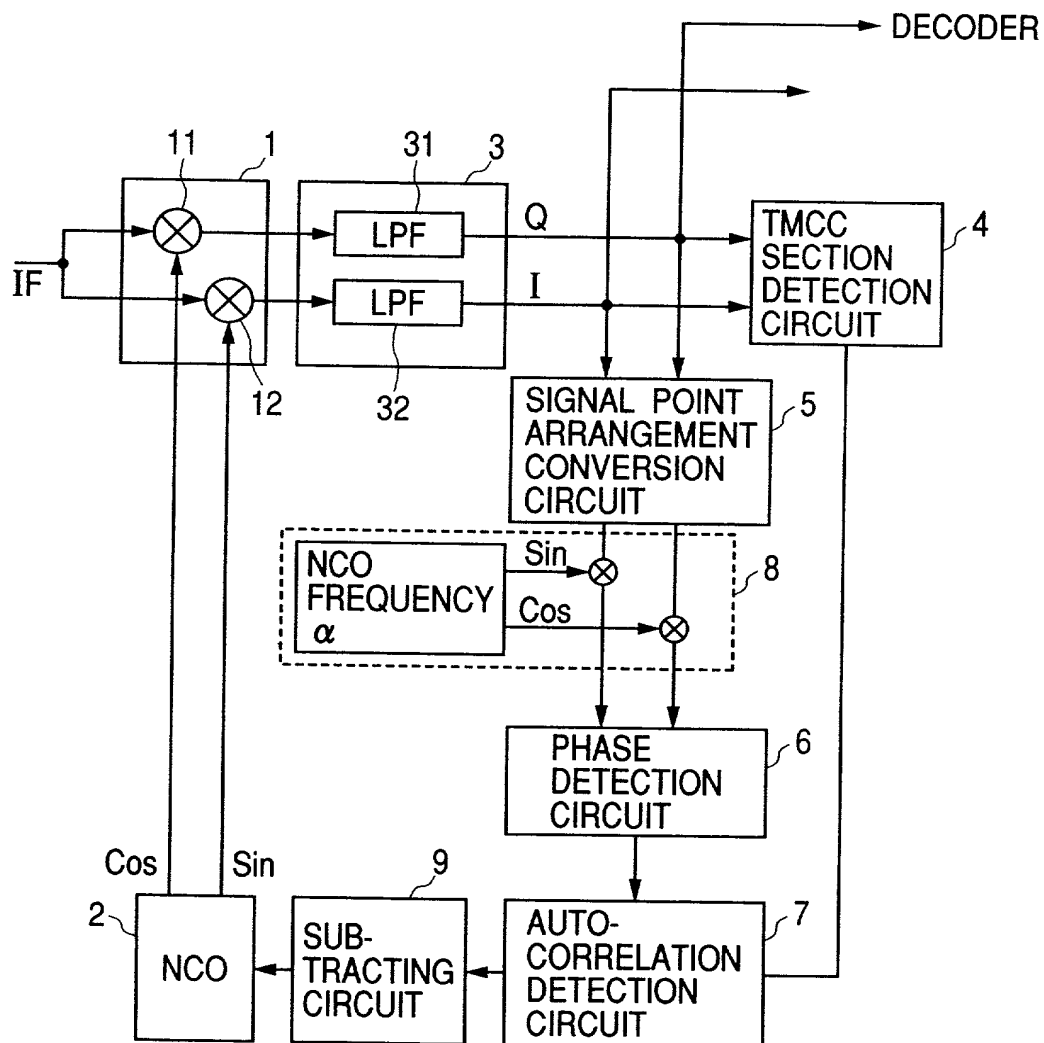


FIG. 2

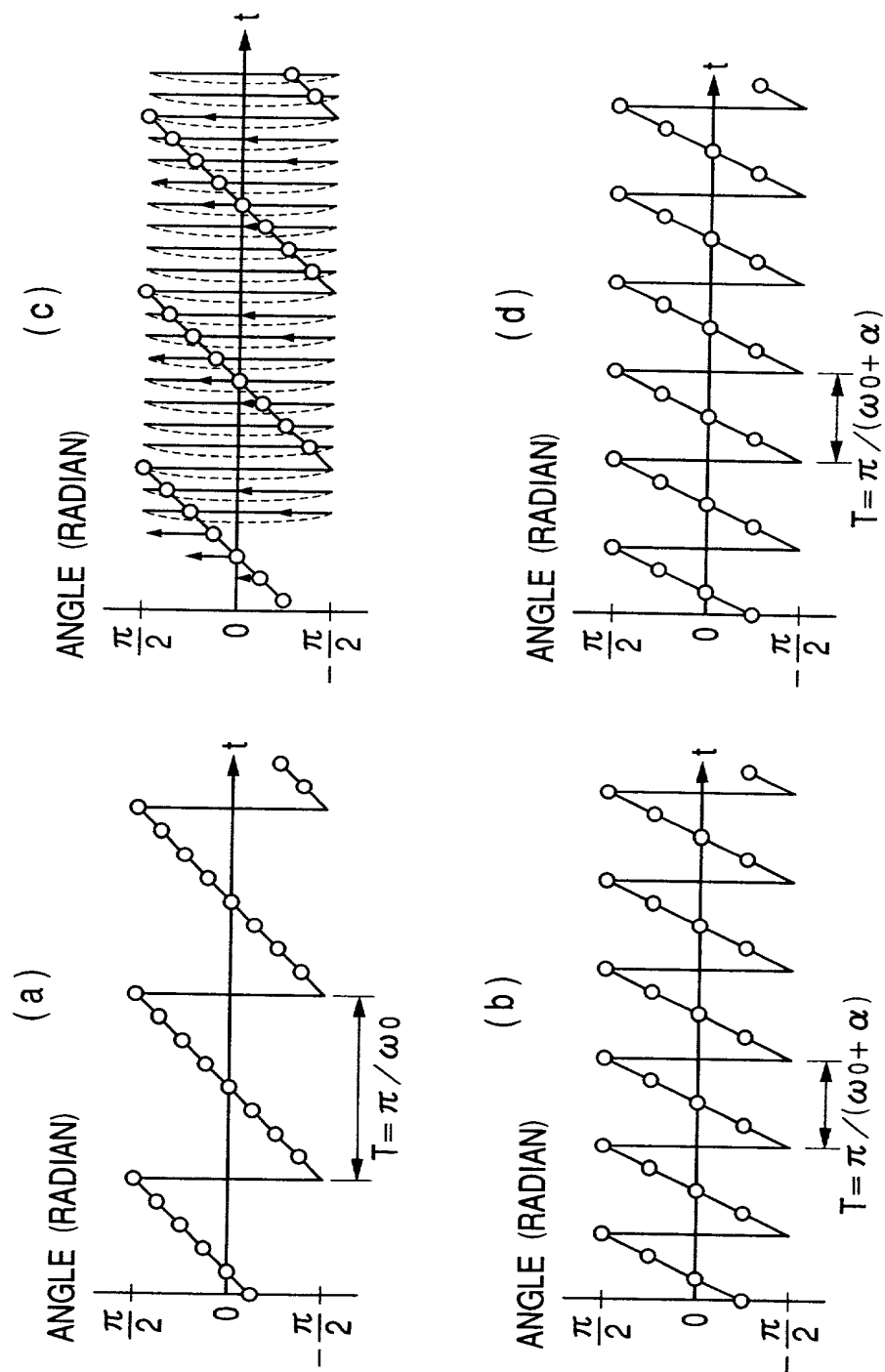
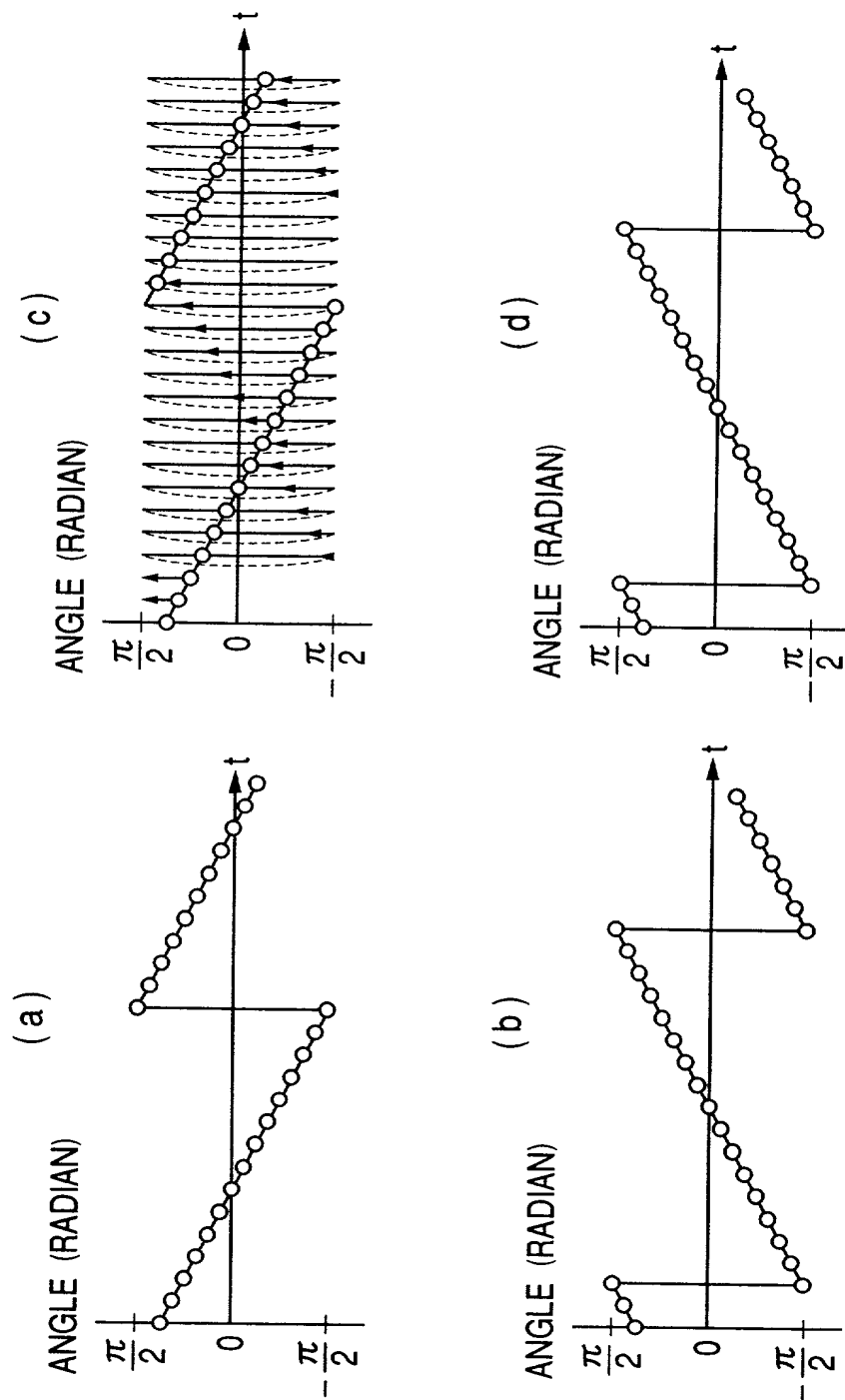
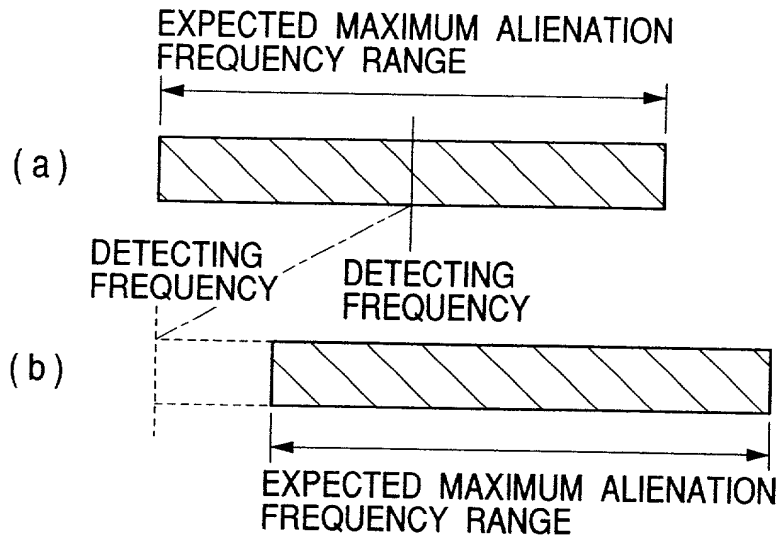
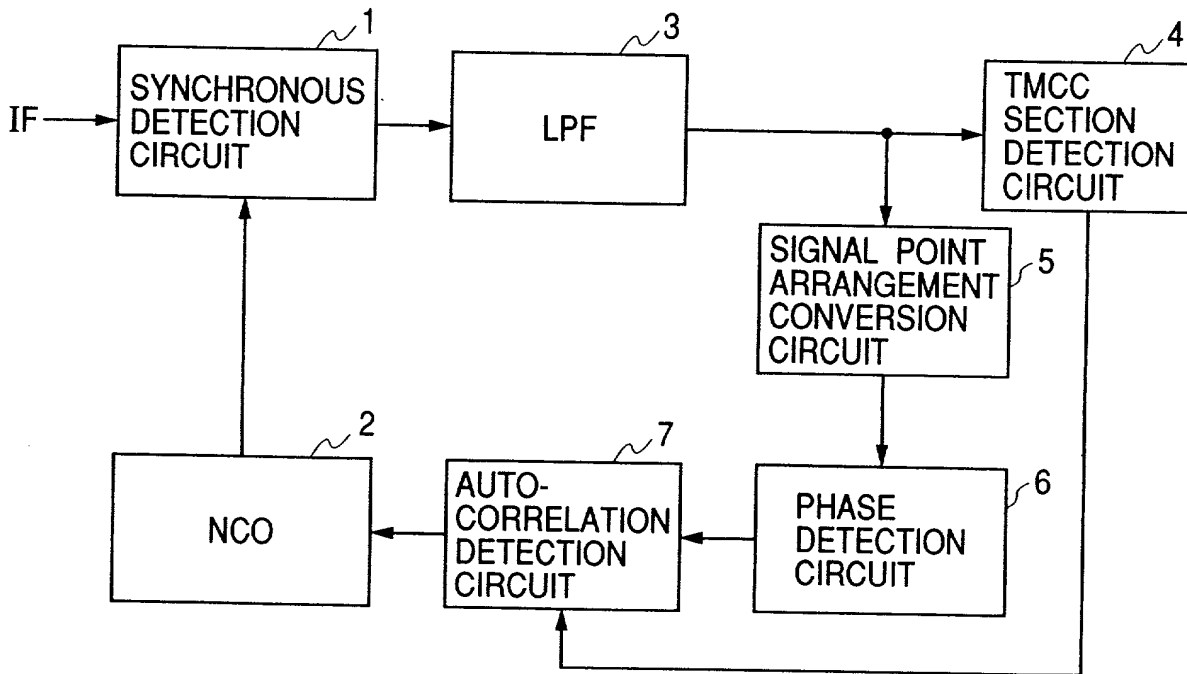


FIG. 3



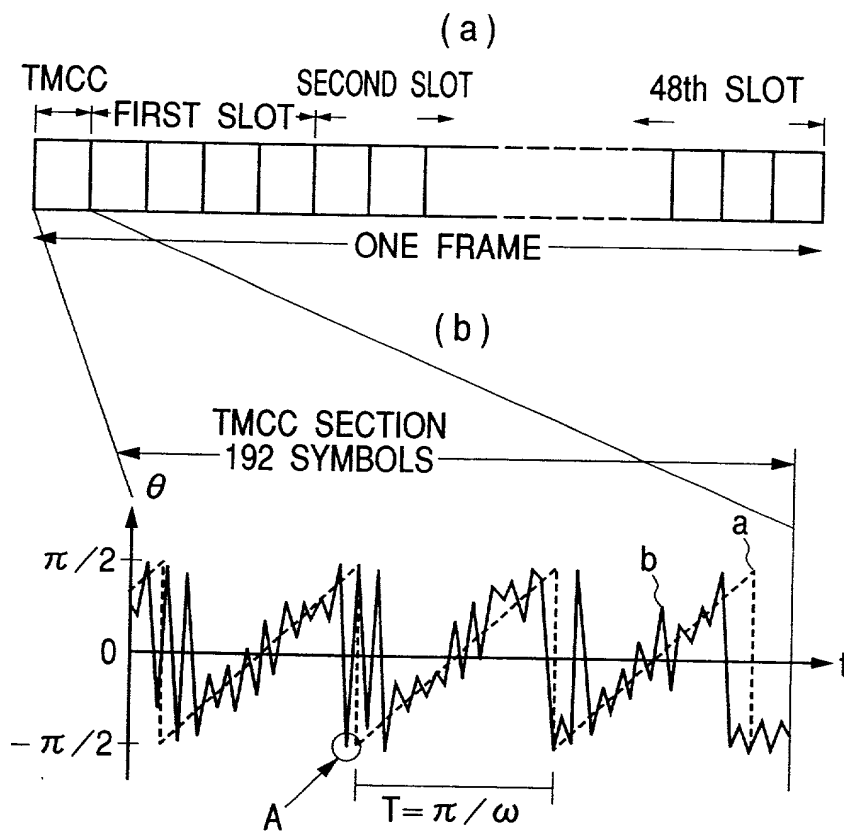
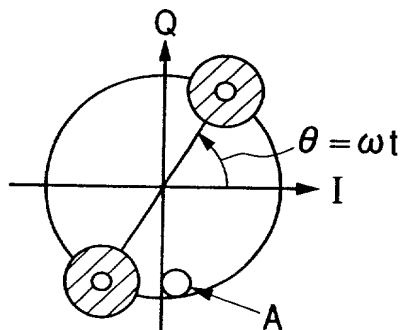
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**FIG. 4****FIG. 5**

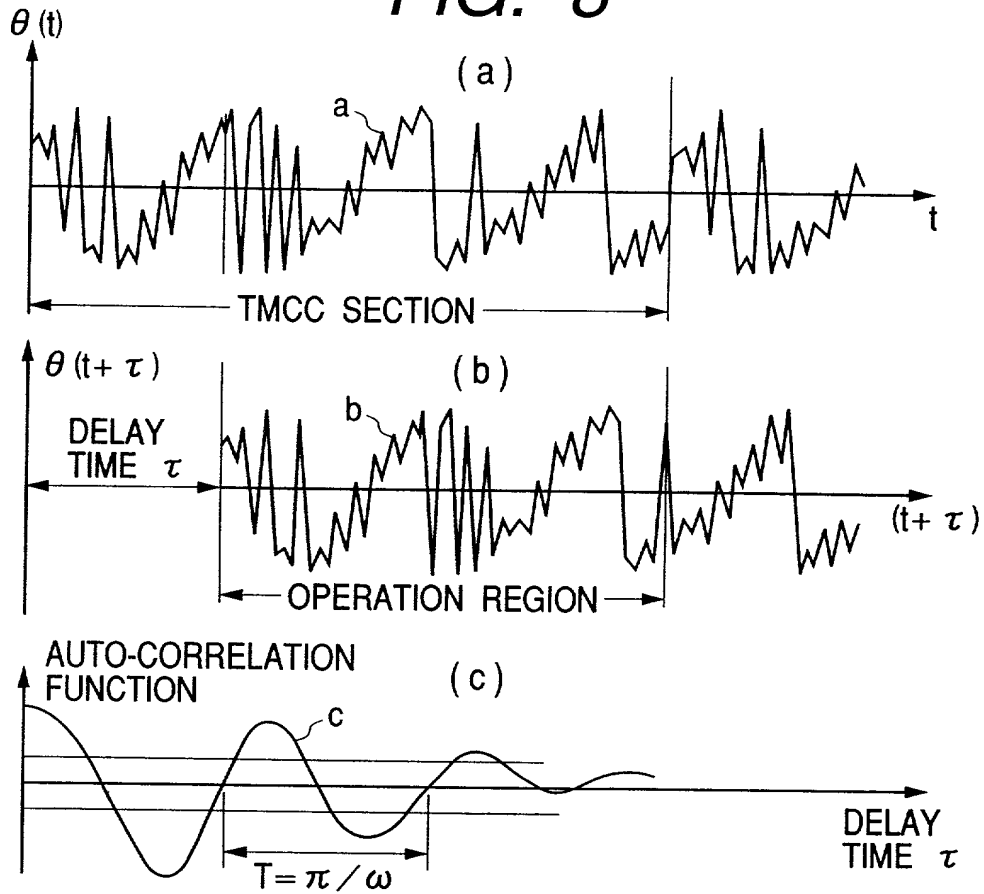
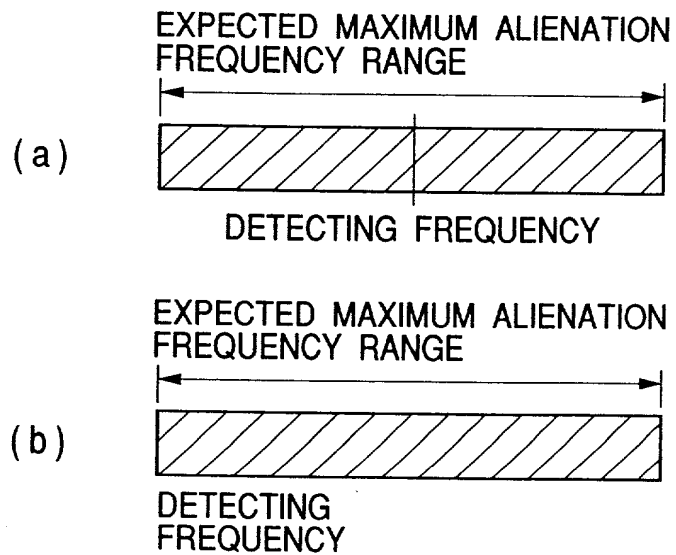
(PRIOR ART)



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**FIG. 6****FIG. 7**

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**FIG. 8****FIG. 9**

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 (Includes Reference to PCT International Applications)

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As a below named inventor, I hereby declare that:

My residence post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: **CARRIER REPRODUCING CIRCUIT**

the specification of which (check only one item below):

☐ is attached hereto.

☐ was filed as United States application

Serial No.

on

and was amended

on \_\_\_\_\_ (if applicable).

☒ was filed as PCT international application

Number **PCT/JP99/04614**

on **August 26, 1999**

and was amended under PCT Article 19

on **January 31, 2000** (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate or of any PCT international applications(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

**PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. 119:**

COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 USC 119
Japan	Patent Appln. No. 10-259128	31.08.98	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO
			<input type="checkbox"/> YES <input type="checkbox"/> NO
			<input type="checkbox"/> YES <input type="checkbox"/> NO
			<input type="checkbox"/> YES <input type="checkbox"/> NO
			<input type="checkbox"/> YES <input type="checkbox"/> NO

## COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY

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I hereby claim the benefit under Title 35, United States Code, § 119(e) or § 120, as applicable of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56 which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application:

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U.S. APPLICATIONS		STATUS (Check one)		
U.S. APPLICATION NUMBER	U.S. FILING DATE	PATENTED	PENDING	ABANDONED
PCT APPLICATIONS DESIGNATING THE U.S.				
PCT APPLICATION NO.	PCT FILING DATE	U.S. SERIAL NUMBERS ASSIGNED (if any)		

**POWER OF ATTORNEY:** As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (List name and registration number)

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

The undersigned hereby authorize any U.S. attorney or agent named herein to accept and follow instructions from Nobuaki KATO and Nobumitsu ASAHI as to any action to be taken in the Patent and Trademark Office regarding this application without direct communication between the U.S. attorney or agent and the undersigned. In the event of a change in the persons from whom instructions may be taken, the U.S. attorneys or agents named herein will be so notified by the undersigned.

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